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ORIGINAL ARTICLE

Popliteo–pedal bypass surgery for critical limb ischemia

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Abstract
Background Critical limb ischaemia due to distal arterial disease represents a significant challenge. Randomised controlled evidence suggests that open surgery may be superior to endovascular intervention but there is limited data on the specific clinical cohort with exclusively infra-popliteal disease.
Aim We analysed indications for, and outcome from all, popliteo-pedal bypass procedures performed between July 1998 to November 2008.
Patients and methods Twenty-eight bypass procedures were performed in 24 patients. Autologous vein was used exclusively. The proximal anastomosis was to the below-knee popliteal artery in all the patients; the distal anastomosis was to plantar artery ($n = 15$) or dorsalis pedis artery ($n = 13$). Mean patient age was 63.Eight years of age (range 37–92 years). Indications for surgery were tissue loss ($n = 21$) and rest pain ($n = 7$). Ultrasound graft surveillance was performed every 6-months.
Results Using life table analysis, primary graft patency was 63.3% at 1-, 3- and 5-years and secondary patency (after three interventions) was 74.6% at 1-, 3- and 5-years. Limb salvage rate was 81.8% after 1-, 3- and 5-years as all five limb amputations were performed in the first 3-months following the surgery. Overall survival was 75, 75 and 47.1% at 1-, 3- and 5-years, respectively. The major amputation free survival rate was 54.2, 54.2 and 21.3% at 1-, 3- and 5-years, respectively. Seventy-nine percent ($n = 19$) patients were diabetic.
Conclusion Our data supports popliteo-pedal bypass as an effective treatment for distal vascular disease. Comparison with endovascular treatment in a randomised trial needs to be performed.

Keywords Popliteo-pedal bypass · Popliteal-distal bypass surgery · Critical limb ischaemia

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Introduction

Peripheral vascular disease (PVD) is extremely common and affects approximately 2.6 million people in the United Kingdom, with 16.6% affected over 55-years of age [1, 2]. In Ireland PVD accounted for 15% of all cardiovascular hospital discharges (100,000 bed days) in 2010, a 4% increase since 1998 [3]. Symptomatic PVD is not a benign condition as up to 50% of those diagnosed will be dead within 10-years [4]. Aggressive attempts to revascularise should be considered for those with end-stage PVD as these have been shown to be cost effective [5, 6]. In addition, a major limb amputation carries a 2-year survival of 50% and just 29% will be alive 5-years after amputation [7, 8].

Various studies [9–11] have shown that even in those with very extensive disease, but patent foot arteries, bypass surgery is an effective treatment for limb salvage. More recently, the use of angioplasty has become much more prevalent with encouraging early results. The long-term outcome remains to be determined. While the limited evidence from randomised controlled trials [12] suggests that open surgery may be preferable to endovascular intervention in preventing limb loss, the BASIL trial [12]

did not specifically focus on the clinical cohort with exclusively infra-popliteal disease.

We set out to evaluate the outcomes in our unit of pedal bypass using the popliteal artery as the inflow vessel over a 10-year period, to provide results against which the results of infra-popliteal angioplasty could be measured.

Patients and methods

We retrospectively reviewed theatre logbooks, medical charts and our computerised patient database to identify all popliteo-pedal bypass operations carried out in our unit between July 1998 and November 2008.

All patients had pre-operative imaging using conventional trans-femoral puncture angiography to identify the proximal and distal anastomotic locations. Patient demographics and the presence of risk factors for vascular disease including diabetes mellitus, hypertension, dyslipidaemia, chronic renal impairment and smoking status were recorded. Renal impairment was defined as per the National Kidney Foundation definition [13]. All bypasses were for limb salvage and indications included ulceration, tissue necrosis, and rest pain.

Technique was standardised among three operating consultant surgeons and consisted of the use of autologous vein exclusively. Patients were heparinised intra-operatively. The long saphenous was identified in the groin and mobilised along its course to the knee. The proximal anastomosis was performed before valvotomy. This was performed using a valvulotome (Le Maitre valvulotome Braun–Aesculap: Atraumatic Vein Valvulotome Dublin, Ireland) to disrupt the valves. The vein was not reversed. The vein was passed through the interosseus membrane to allow the graft to enter the anterior compartment of the leg where the distal site was onto the dorsalis pedis artery. A tunneling device (long vascular clamp or a laparoscopic atraumatic grasper) was used to pass the vein graft into the anterior compartment. An intermediate anterior incision was frequently required to facilitate the passage of the graft to the foot interosseous membrane. Sharp angulation at the distal anastomosis must be avoided as the graft exits the interosseus membrane to prevent graft compression. Where the plantar artery was the distal target (Fig. 1), the vein was passed subcutaneously to the target site using a long arterial clamp or laparoscopic grasper. 6/O polypropylene was used at the proximal and 7/0 polypropylene for the distal anastomoses. The proximal wound was closed in layers using 3-0 poliglecaprone 25 (monocryl) and 4-0 poliglecaprone 25 for skin. The distal wounds were closed with interrupted 4-0 nylon or subcutaneous poliglecaprone 25.

Post-operatively, patients were continued on a heparin infusion followed by clopidogrel or warfarin when there was another medical indication. Operation notes were reviewed to ensure accurate recording of the operation performed including graft type and site of proximal and distal anastomosis. All patients were routinely reviewed every 6-months in outpatient clinics after surgery and at these visits ultrasound graft surveillance was routinely carried out. Telephone calls with General Practitioners and the patients allowed us to complete current follow-up for those no longer attending outpatient clinics.

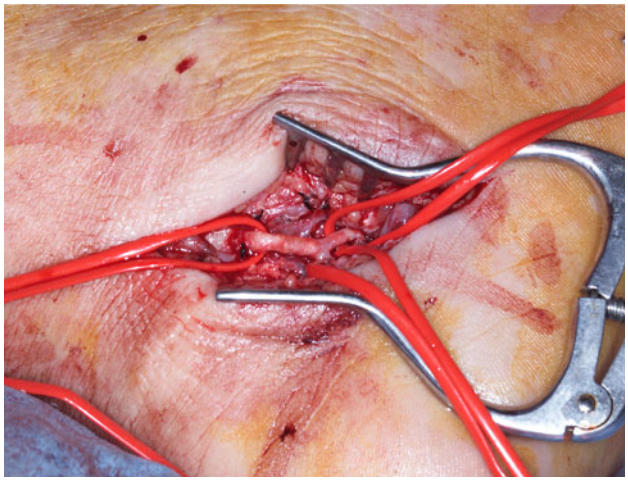


Fig. 1 Common plantar artery exposed for distal anastomotic location

Data was tabulated in a Microsoft Excel spreadsheet (Microsoft, Dublin, Ireland) and analysed using the life table technique for the primary end points which included: overall survival, primary and secondary graft patency and major amputation free survival. Major amputation free survival was defined as survival free from any amputation proximal to the phalanges.

Results

In total, 24-patients had unilateral bypass procedures, four of whom later had a contralateral bypass procedures performed. Ages ranged from 37-years to 92-years of age at bypass (mean = 63.8 years). Twenty patients were male (83%). In all cases, the below knee popliteal artery was used as the inflow vessel. The distal anastomosis was to the plantar artery in ($n = 15$) and to the dorsalis pedis artery in ($n = 13$). Autologous vein was used in all cases, the ipsilateral long saphenous vein (LSV) was used in 22 cases, the contralateral LSV in the other cases. All patients had exclusively infra-popliteal disease, confirmed on angiography (Fig. 2).

During the 10-year time period, a total of 218 lower limb bypass procedures for critical limb ischaemia were performed in our unit. Popliteo-pedal bypasses reported here represented 12.8% of the total number of bypass

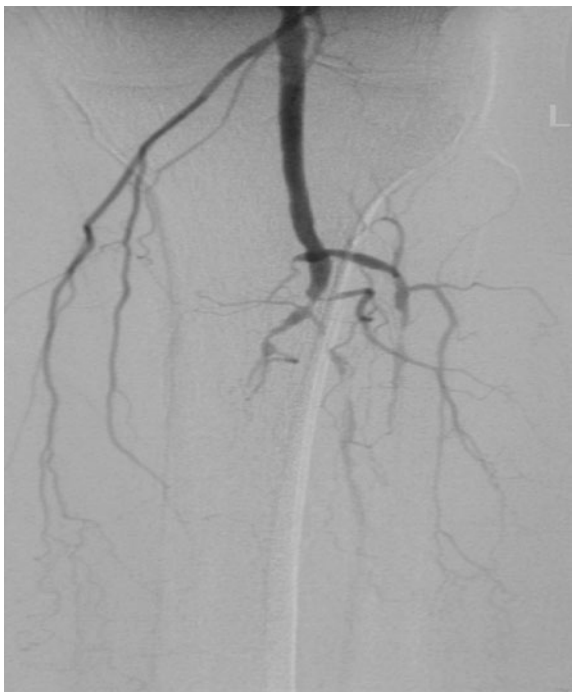


Fig. 2 Pre-operative angiogram showing infra-popliteal arterial occlusion

Table 1 Co-morbidities in patients undergoing popliteo-pedal bypass surgery

Risk factor	*n*
Diabetes mellitus	19
Hypertension	15
Dyslipidaemia	13
Renal impairment	9
Smoker	14

Table 2 Indications for popliteo-pedal bypass surgery

Indication for procedure	*n*
Ulceration	12
Rest pain	7
Tissue necrosis	9
Total	28

operations. In the later years, percutaneous angioplasty was performed in selected patients with similar disease patterns (55 distal angioplasties were performed during the final 15-months of the study period). Risk factors and indications for bypass surgery are displayed in Tables 1 and 2.

Primary graft patency

Three grafts failed within 30-days, five more failed after 3-months and after 1-year a total of 10 grafts were not patent or had required a salvage procedure. The outcomes of these graft failures are shown in Table 3. This yielded a primary patency at 1-, 3- and 5-years of 63.3%. In two of these cases, although the grafts were occluded, the limbs were intact.

Secondary graft patency

Three grafts required additional intervention to maintain patency. These interventions comprised a balloon angioplasty of the proximal anastomosis after 6-months, an infra-malleolar jump graft from common to lateral plantar artery after 9-months and revision of the distal anastomotic site from dorsalis pedis to lateral plantar artery after one month (see Table 3). This yielded a secondary patency at 1-, 3- and 5-years of 74.6% (Fig. 3).

Limb salvage

There were a total of five below knee amputations, two of which occurred within the first 30-days and three more after 3-months. No late amputations were performed. Limb salvage rates were 81.8% at 1-, 3- and 5-years (Fig. 4).

Overall survival

One patient died within 30-days, four died after 6-months and one more patient died after 1 year. After 5 years a total of ten patients had died. This yielded 1-, 3- and 5-year survival rate of 75, 75 and 47.1%, respectively (Fig. 5).

Major amputation free survival

The major amputation free survival was 54.2, 54.2 and 21.3% at 1-, 3- and 5-years, respectively (Fig. 6).

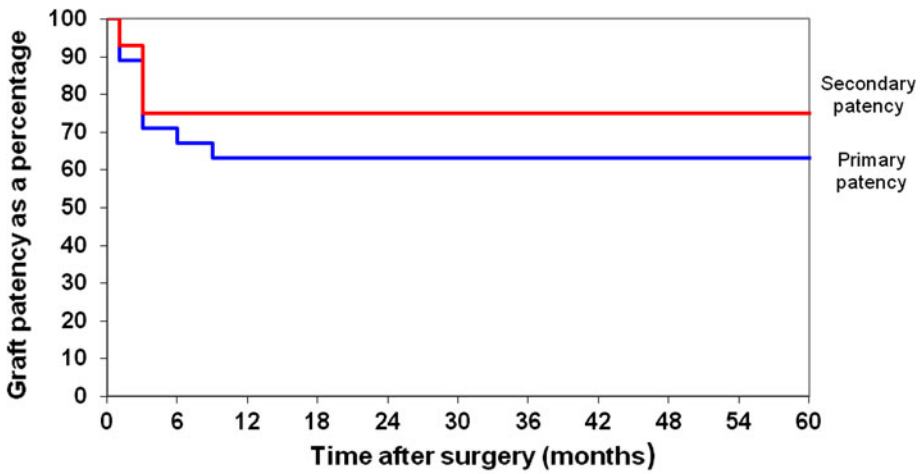
Discussion

These results demonstrate that popliteo-pedal bypass surgery as performed in our vascular unit is comparable with worldwide results [9–11] in terms of overall survival and primary patency rates. Our primary patency rate of 63.3% at 5-years compares favourably with other published results [14–18] including the recently published meta-analysis [19] which quoted a 5-year pooled primary patency rate of 63.1% and also a larger study of inframalleolar bypasses [20]. Of note, not all of these studies were exclusively below knee popliteal to pedal bypasses.

In the last decade there has been a massive leap forward in the knowledge, application and technology of endovascular intervention. Most studies describing the experience with this rapidly evolving technique [21–23] have reported

Table 3 Outcomes from graft failures

Patient number	Time (months) post-op	Number of graft failures	Outcome/intervention
1	1	1	Below knee amputation
2	1	1	Revision of distal anastomosis from dorsalis paedis to lateral plantar artery
3	1	1	Below knee amputation
4	3	1	Below knee amputation
5	3	1	Limb survived (without intervention)
6	3	1	Below knee amputation
7	3	1	Limb survived (without intervention)
8	3	1	Below knee amputation
9	12	1	Angioplasty of proximal anastomosis
10	12	1	Jump graft from common plantar artery to lateral plantar artery



Primary Patency

Time intervals (months):					
0	12	24	36	48	60
Numbers Remaining at time interval:					
28	16	14	13	9	4

Secondary Patency

Time intervals (months):					
0	12	24	36	48	60
Numbers Remaining at time interval:					
28	19	16	15	11	6

Fig. 3 Graph showing primary and secondary graft patency after popliteo-pedal bypass surgery. Legend: *x*-axis: Time since surgery in months. *y*-axis: Graft patency as a *percentage*

short to mid range outcomes. Randomised control evidence [12] suggests that the results of bypass surgery may be better than endovascular intervention but this study was not confined to the cohort of patients with exclusively infra-popliteal disease.

Recent meta-analysis of infra-popliteal angioplasty for critical lower limb ischemia showed a primary patency rate at 3-years of 48.6% [24]. The 3-year primary patency rate of 63.4% in this series is favourably comparable. Our results demonstrate that impressive results can be achieved by popliteo-pedal bypass surgery.

Overall survival in our patient population with multiple co-morbidities is equivalent to other major studies [9–11, 14–18]. Long-term survival results for endovascular intervention are still awaited.

The study's major amputation free survival rate (54.2, 54.2 and 21.3% at 1-, 3-, 5-years) compared similarly with other large distal bypass studies (74, 56 and 29%) [25].

Interestingly in our group of patients, a significant proportion of patients had chronic renal impairment (39%). This is significant both because the literature suggests worse outcome in patients with end stage renal disease [26]

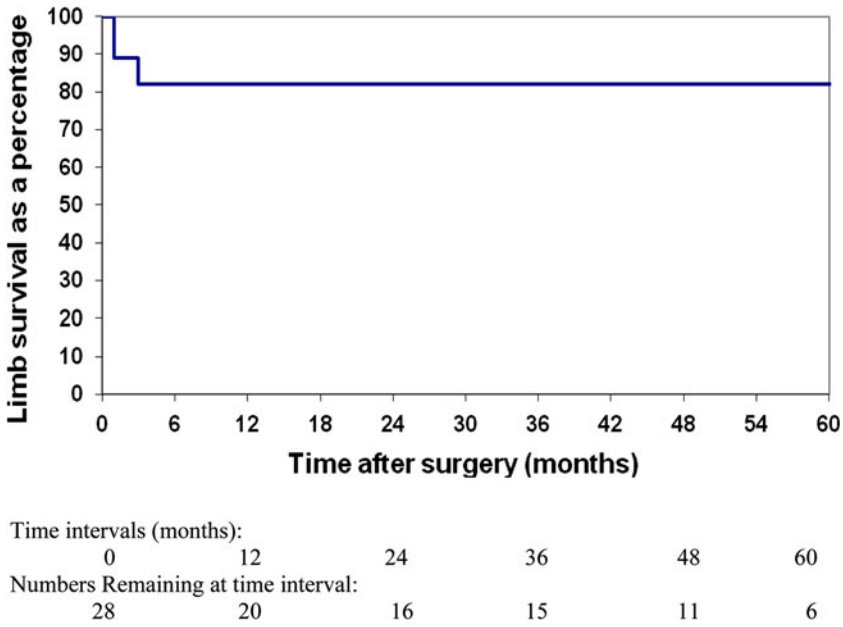


Fig. 4 Graph showing limb survival after popliteo-pedal bypass surgery. Legend: *x*-axis: Time since surgery in months. *y*-axis: Limb survival as a *percentage*

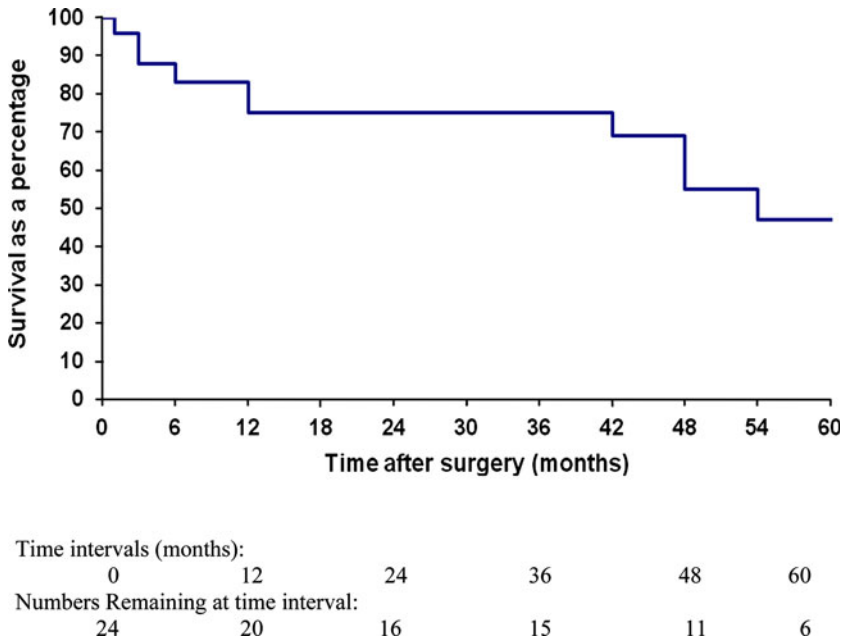


Fig. 5 Graph showing overall survival for popliteo-pedal bypass surgery. Legend: *x*-axis: Time since surgery in months. *y*-axis: Overall survival as a *percentage*

and also because of newer techniques like endovascular intervention which requires the use of nephrotoxic contrast agents [27].

Outcomes following major amputation for critical limb ischaemia are poor with up to 50% of patients becoming institutionalised. The limb salvage rate at 5-years in our series is 81.8%. The total cost of vascular reconstruction compared with primary amputation has been shown to be significantly lower than primary amputation for health care systems [5, 6]. These results clearly show that the use of popliteo-pedal bypass surgery can dramatically alter the costly outcomes for patients with critical lower limb ischaemia. These results strongly indicate that popliteo-pedal bypass surgery is still a valid and cost effective option in selected patients.

Conclusion

Critical lower limb ischaemia is associated with significant morbidity and decreased life expectancy. The use of lower limb amputation is associated with high rates of institutionalization and hence long-term cost to health care systems. Aggressive revascularisation, in the form of

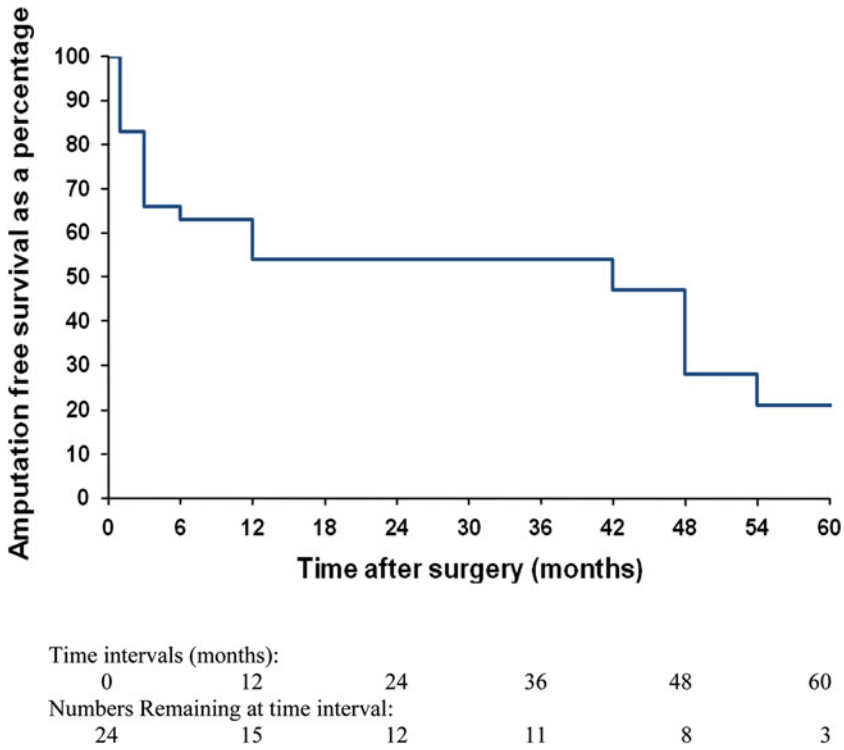


Fig. 6 Graph showing major amputation free survival for popliteo-pedal bypass surgery. Legend: *x*-axis: Time since surgery in months. *y*-axis: Major amputation free survival as a *percentage*

popliteo-pedal bypass surgery should still be considered in selected patients with extensive infra-popliteal disease. Comparison with endovascular treatment in a randomised trial setting should to be performed.

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Conflict of interest No conflicts of interest.

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